

Analysis of Spectrum Sensing of Cognitive Radios by Energy Detection method

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Abstract- This research work gives an overview of the method associated with the practical implementation of spectrum sensing in Cognitive radio systems by using Energy Detection. Energy Detection can be used most efficiently for spectrum sensing of Cognitive Radio Networks. This approach doesn't require any information about primary user as rest other approaches requires. This makes it more efficient and can be easily implemented for Spectrum Sensing. The efficiency of spectrum is being increased by the unlicensed access of unused frequency band across the licensed radio spectrum. This access of unused frequency spectrum doesn't affect the performance or operation of licensed user. Cognitive radio network is very effective in radio technology, as it allows all the vacant frequency bands utilized by the secondary users at that time when its primary license holders are not using it. Cognitive radios have the potential to jump in and out of un-used spectrum gaps to increase efficiency and provide wideband services. ROC of Spectrum Sensing for different SNR values and different time bandwidth factor has been analysed.

Keywords: Cognitive Radios (CR); Signal to Noise Ratio (SNR); Receiver Output Characteristics (ROC); Primary User (PU); Additive White Gaussian Noise (AWGN).

I. INTRODUCTION

CR systems can be used to improve the efficiency of the uses of various resources in wireless communication systems. Spectrum has been identified as a scarce resource and its efficient use is of most important [1]. In terms of spectrum, various deployment scenarios are envisaged for CR systems, depending on the types of spectrum bands considered. Here, three deployment scenarios has been identified i.e. Licensed Spectrum, Unlicensed Spectrum, Primary-secondary setting.

In the first scenario, it is visualized that CR techniques will be deployed on licensed spectrum bands by the owner of the spectrum to improve the efficiency of its spectrum use, e.g. to accommodate more traffic on the same band. In this case, CR features could be introduced gradually into future developments of current systems that have sole rights to use the given spectrum. Examples of this include mobile communication systems in which operators deploy home base stations on the same spectrum bands, as their macro cells to accommodate more traffic in the same area. This kind of CR operation does not require any regulatory considerations as it is an internal system issue.

In the second scenario, CR techniques could be employed to improve use of spectrum in unlicensed bands. By using CR techniques, more data should be accumulated on the same spectrum band. Different systems use the ISM band as an alternative way. For e.g. balancing the load at peak hours by offloading delay-tolerant data to ISM bands with the aid of CR techniques. The current systems using the ISM bands could be enhanced with CR features to improve their performance [2].

In the third scenario, CR systems could make opportunistic use of temporarily and locally available spectrum that belongs to higher priority systems. Here, the prerequisite for allowing this kind of operation is that the CR

system is not allowed to cause harmful interference to the higher priority systems. Examples of this primary or secondary user setting include TV white space discussions in which CR systems use TV spectrum in the band 470–790 MHz.

In the other scenario, different CR systems coexist with each other on the same spectrum bands following some set of coexistence rules. This is similar to ISM (Industrial, Scientific and Medical) bands in which different systems share the same spectrum but the spectrum use is predicted to be much more efficient, as it has been the major design aim [3]. In all of these scenarios, the key topic is the coexistence of several systems on a given spectrum band. The systems can have similar or different access technologies and equal or unequal priority.

Software Radio is an emerging technology that provides platform for flexible radio systems, multiservice, multi-standard, multiband, reconfigurable and reprogrammable by software for PCS (Personal Communications Service). Cognitive radio extends the software radio with radio-domain model-based reasoning about such radio etiquettes enhancing the flexibility of personal services through a Radio Knowledge Representation Language (RKRL).

II. ENERGY DETECTION METHOD

Energy detection also called as non-coherent detection is the signal detection mechanism using an energy detector (also known as radiometer) to specify the presence or absence of signal in the band [4]. The most often used approaches in the energy detection are based on the Neyman-Pearson (NP) lemma. The NP lemma criterion increases the probability of detection (P_d) for a given probability of false alarm (P_{fa}). It is an essential and a common approach to spectrum sensing since it has moderate computational complexities, and can be implemented in both time domain and frequency domain. To adjust the threshold of detection, energy detector requires knowledge of the power of noise in the band to be sensed. Compared with energy detection, matched filter detection and cyclostationary detection which require a priori information of the PUs to operate efficiently, which is hard to realize practically since PUs differ in different situation. Energy detection is not optimal but simple to implement, so it is widely adopted.

In this technique there is no need of prior knowledge of Primary signal energy. No is the one sided noise power spectral density.

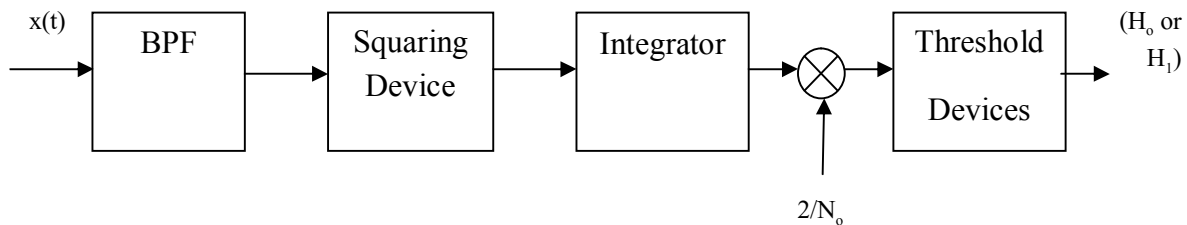


Figure 1: Block Diagram of Energy Detection Method [5].

Where H_o = Absence of User.

H_1 = Presence of User.

The block diagram for the energy detection technique is shown in the Figure 1. In this method, signal is passed through band pass filter of the bandwidth W and is integrated over time interval. The output from the integrator block is then compared to a predefined threshold. This comparison is used to discover the existence of absence of the primary user. The threshold value can set to be fixed or variable based on the channel conditions [5].

$$y(k) = n(k) \dots \dots \dots H_o \quad (1)$$

$$y(k) = h * s(k) + n(k) \dots \dots H_1 \quad (2)$$

Where $y(k)$ is the sample to be analyzed at each instant k and $n(k)$ is the noise of variance σ^2 . Let $y(k)$ be a sequence of received samples $k \in \{1, 2, \dots, N\}$ at the signal detector, then a decision rule can be stated as:

$$H_0, \dots \text{ if } \epsilon > v \quad (3)$$

$$H_1, \dots \text{ if } \epsilon < v \quad (4)$$

Where $= E |y(k)|^2$ the estimated energy of the received signal and it is chosen to be the noise variance σ^2 . However Energy Detector is always accompanied by a number of disadvantages are: i) sensing time taken to achieve a given probability of detection may be high. ii) Detection performance is subject to the uncertainty of noise power. iii) Energy Detector cannot be used to detect spread spectrum signals [6].

Energy Detection technique is the most efficient technology which gives very near-by spectrum sensing results. The energy Detector technique consist of main three steps as mentioned below:

Noise Pre-Filter: As the name shows, this stage is used to remove out the noise present in the input signals; also this stage is used Band limiting filter, which is used to pass the signal of specific band as per the requirement.

Squaring Device: The pre-filtered signal is further processed with this squaring device. This squaring device has flat spectral density which square the band limited signal, this squaring process is use to measure the energy which is received to the signal by comparing it with the input signal.

Integrator: The name itself tells about the meaning of itself. This integrating device is used to determine the time interval of the received signal, the output of this integrated signal is normalized by $N_0/2$ where N_0 is Noise Power density.

Getting the output of this entire system:

$$y(t) = \begin{matrix} n(t) & \text{(Signal without noise)} \\ h s(t) + n(t) & \text{(Signal with noise)} \end{matrix}$$

$$Pd = \Pr (Y > \lambda / H_1) \quad (5)$$

$$Pf = \Pr (Y > \lambda / H_0) \quad (6)$$

Taking λ as the threshold level.

$$Pd = Q_u [(2y)^{1/2}, (\lambda)^{1/2}] \quad (7)$$

$$Pf = Q(u, \lambda/2) / Q(u) \quad (8)$$

Where: $Y = \sigma_s^2/2$

Q_u is a generalized Marcum's Q Function.

III. RESULTS AND DISCUSSION

By simulating all the expressions discussed above, Energy Detection Technique is being implemented. All the simulations is done in MATLAB under AWGN channel. In Energy Detection Technique, Receiver output characteristics (ROC) [8] plays very important role in signal detection theoretically because this techniques deals in trade-off between Pd and Pfa.

Figure 2 shows the ROC of spectrum sensing for different SNR. Here the time bandwidth factor is $(u) = 100$ and SNR is taken as 0 dB to 25 dB with Pfa = 0.01, This plot shows that the signal detection is directly proportional to the increase in SNR. When SNR is 5 dB - 7 dB, detection probability is very poor i.e. below 0.05. But when the detection probability increases respectively, it reaches with detection probability 1 when SNR is 17 dB - 18dB.

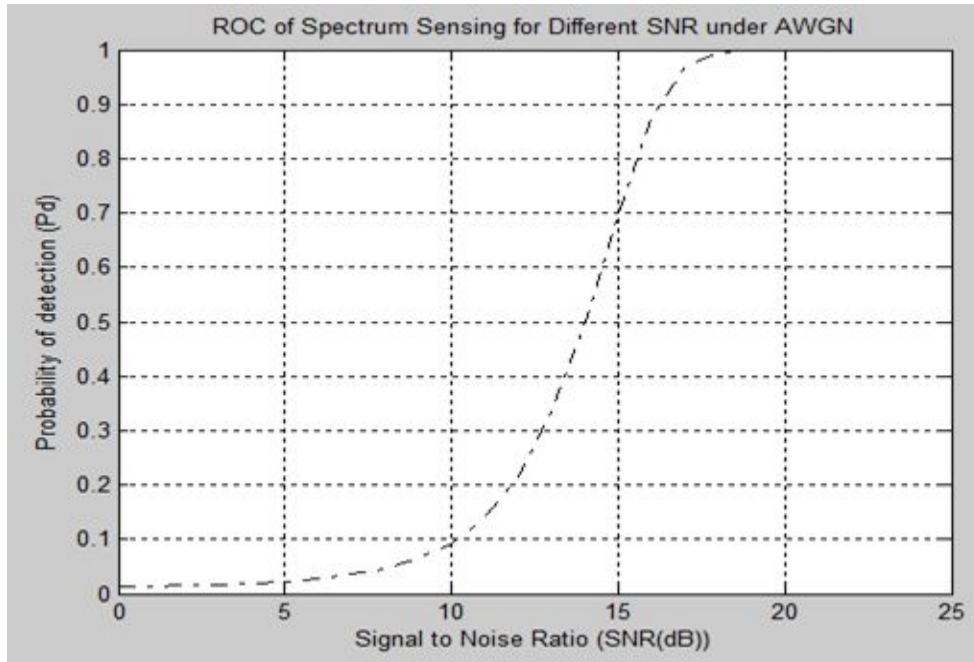


Figure 2: ROC of Spectrum Sensing for different SNR with $u=100$.

By taking the comparison of different time bandwidth factor (u) = 100,200,400,800 and at different SNR from 0 dB to 25dB, with $P_{fa} = 0.01$, under AWGN channels, the Receiver Output Characteristics of this technique has been estimated as below:

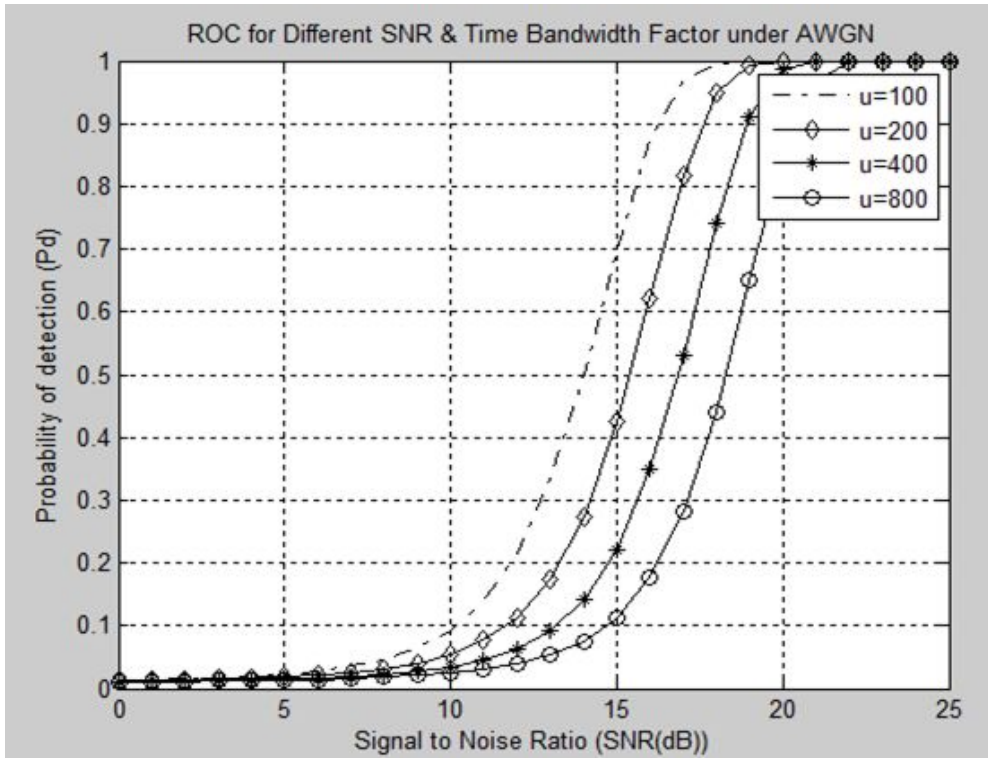


Figure 3. Comparison of ROC of spectrum sensing for different SNR and Time bandwidth factor

This ROC shows that when Time bandwidth Factor (u) of signal increases, this will decrease the probability of detection of the signal. Probability of detection always increases with increase in SNR.

CONCLUSION

Study of performance for Energy Detection method is done by artificially simulating it with AWGN channel. This approach is simulated over several Time bandwidth factors and SNR; however for simplicity, the results obtained for few are mentioned. The results demonstrate that Probability of detection always increases with the increase in SNR and on other hand decreases with the increase in time bandwidth factor. Energy detection method is capable of spectrum sensing without interfering primary users. This technique is highly efficient in spectrum sensing for local channels under AWGN signals.

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